MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

ETN4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(All sections/Groups)

3 MARCH 2020
2:30 P.M. – 4:30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with 4 Questions only.
2. Answer **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1 (25 marks)

Table 1 lists the parameters of two optical fibers.

Table 1: Paramaters of optical fiber A and B

Optical fiber	Index profile	Numerical aperture (NA)	Refractive index difference	Core diameter (μm)
A	Step index	0.14	0.36 %	8.2
B	Graded index	0.20	1%	50

(a) Calculate:

(i) The core refractive index of both fibers. [4 marks]

(ii) The acceptance angle of both fibers. [4 marks]

(iii) The normalized frequency of both fibers at wavelength 1.55 μm. [4 marks]

(b) From your answer in Part (a)(iii), identify which fiber operates as a single mode fiber at 1.55 μm. Justify your answer. [2 marks]

(c) Estimate the number of modes in optical fiber B at wavelength 1.55 μm, if the index profile is 2.2. [2 marks]

(d) Which fiber is suitable for long haul optical communication system? Give **TWO(2)** reasons to support your answer. [3 marks]

(e) Compare the two fibers in terms of installation cost and the type of suitable light source. [4 marks]

(f) Identify which fiber has worst pulse broadening at the wavelength of 1.55 μm. Give **ONE(1)** reason to justify your answer. [2 marks]

Question 2 (25 marks)

(a) Describe the process of obtaining amplified coherent emission in laser. [5 marks]

(b) With the aid of a suitable diagram, describe the spontaneous emission process in a forward bias *p-n* junction semiconductor. [4 marks]

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(c) Compare the laser and light emitting diode (LED) light in terms of its coherency and linewidth. [2 marks]

(d) Explain the detection process in a *p-n* photodiode. Include a suitable diagram in your answer. [5 marks]

(e) Describe the term quantum efficiency. Why is the quantum efficiency generally less than unity? [4 marks]

(f) With the aid of an energy level diagram, describe the amplification process in an erbium doped fiber amplifier (EDFA). [5 marks]

Question 3 (25 marks)

(a) Comparing *p-i-n* photodiode and avalanche photodiode, which type of photodetector experience higher noise? Give **ONE(1)** reason to justify your answer. [3 marks]

(b) Distinguish dark current noise and thermal noise in an optical receiver. [4 marks]

(c) A *p-i-n* photodiode has a quantum efficiency of 75% at a wavelength of 0.85 μm. It has a capacitance of 9 pF. The post detection bandwidth of the receiver is 25 MHz. Determine:

(i) The responsivity of the photodiode [2 marks]

(ii) The load resistance. [2 marks]

(iii) The mean photocurrent when the detector is illuminated with 6 μW of optical power. [2 marks]

(iv) The rms quantum noise current. [3 marks]

(v) The rms dark current noise if the dark current is 3 nA. [3 marks]

(vi) The rms thermal noise current if at a temperature of 25°C. [3 marks]

(vii) The signal-to-noise ratio (SNR) in dB. [3 marks]

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Question 4 (25 marks)

Table 2, 3 and 4 list the components that are available at your company.

Table 2: Optical source

Source type	Central wavelength	Average fiber-coupled power	Spectral width
InGaAsP laser diode	1550 nm	-13 dBm	3 nm
GaAlAs laser diode	850 nm	0 dBm	10 nm
InGaAsP LED	1300 nm	-10 dBm	30 nm

Table 3: Optical detectors

Detector type	Receiver Sensitivity (in dBm) function in terms of data rate B
InGaAs *p-i-n* photodiode (at 1550 nm)	$P_R = 8 \log B - 28$ (B in Gbps)
InGaAs *p-i-n* photodiode (at 1300 nm)	$P_R = 11.5 \log B - 60.5$ (B in Mbps)
InGaAs APD (at 1550 nm)	$P_R = 5 \log B - 38$ (B in Gbps)
Silicon APD (at 850 nm)	$P_R = 9 \log B - 68.5$ (B in Mbps)

Table 4: Optical fibers

Fiber type	Attenuation at 850 nm (dB/km)	Attenuation at 1300 nm (dB/km)	Attenuation at 1550 nm (dB/km)
SMF	1.2	0.3	0.2
Graded-index MMF	2.3	0.6	Not given in the datasheet

(a) Using power budget analysis, design a digital link with a length of 30 km that can accommodate a bit rate of 4 Gbps. The system margin should be at least 7 dB. From Table 2, 3 and 4, choose a suitable wavelength, an optical source, a fiber, and a receiver for the link. Fiber coupling loss at the source and detector is 0.1 dB each. The splice loss is 0.05 dB each. There are total of 6 splice points along the link. Show the detail evaluation process in making your decision. Each selection must be justified. [13 marks]

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(b) You are assigned to another project to utilize graded-index multimode fibers (MMF). If the system operates at 500 Mbps, and the system margin is 6 dB, estimate the maximum transmission distance that the link can cover. The source and detector coupling loss is 1 dB each. Assume that splice loss is negligible. Evaluate for both 1300 nm and 850 nm wavelengths. [12 marks]

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	e	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

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